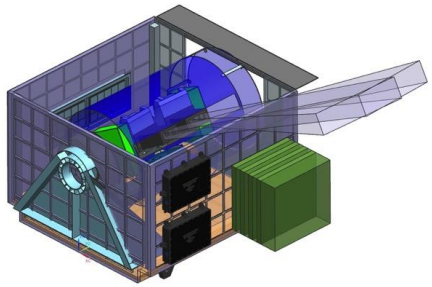
SPIE. REMOTE SENSING 2017

LEARN.
CONNECT.
DO BUSINESS.

Multiangle Spectropolarimetric Imagers for Aerosol

Giacomo Mariani

John C. Pearson, Kevin Burke, David J. Diner



Superconducting Materials and Devices Group
NASA Jet Propulsion Laboratory - California Institute of Technology

September 14, 2017

Introduction

Agenda

- Particulate matter and health
- Spectropolarimetric imager description
- Observing modalities
- Camera architecture
- Focal Plane Module
- Packaging
- Spectropolarimetric filters
- Conclusions

Particulate matter (PM) impacts on human health

Science framework

Airborne PM is a well-known cause of cardiovascular and respiratory diseases.

Coarse particles (PM_{10}-$PM_{2.5}$) irritate our respiratory systems.

Fine particles ($PM_{2.5}$) penetrate deep into our lungs. Toxins can migrate to other organs.

- Heart attacks
- Stroke
- Lung disease, lung cancer
- Aggravated asthma
- Low birth weight and preterm delivery

Importance of particle type

3

Slicing up the spectrum

	UV	Visible							Near-IR		Shortwave IR			
Band (nm)	367	389	415	445	551	645	749	762.5	864	943	1039	1607	1880	2126

polarimetric | absorbing particles | fine particles | coarse particles

- ✓ Although PM is implicated in many adverse health impacts, the relative toxicity of specific **PM types** is not well understood
- ✓ PM "type" refers to the fractional proportions of PM_{10}, $PM_{2.5}$, and $PM_{2.5}$ components (sulfate, nitrate, organic carbon, black carbon, dust)
- ✓ According to the US EPA (2013)
  - The evidence is not yet sufficient to allow differentiation of those constituents or sources that may be more closely related to specific health outcomes.
  - *The use of central fixed-site monitors to represent population exposure is a key factor limiting our knowledge as to which PM types pose the greatest health risks.*

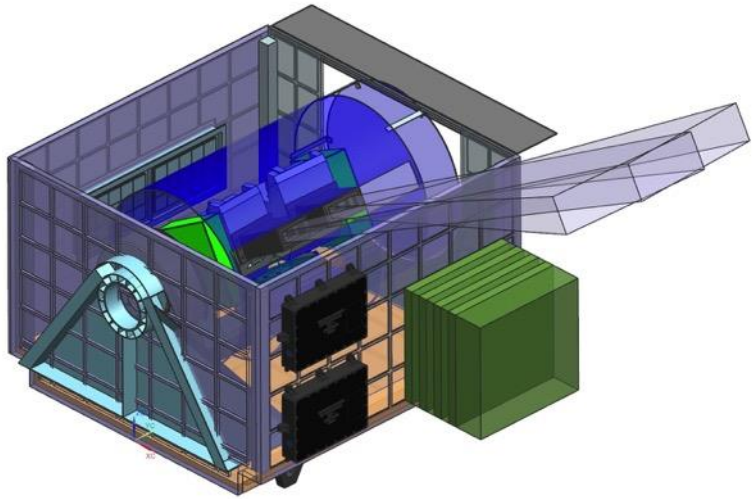
Imager and Applications

Technical capabilities

Instrument

Two pushbroom spectropolarimetric cameras on a 2-axis gimbal

A bit larger than a large microwave oven

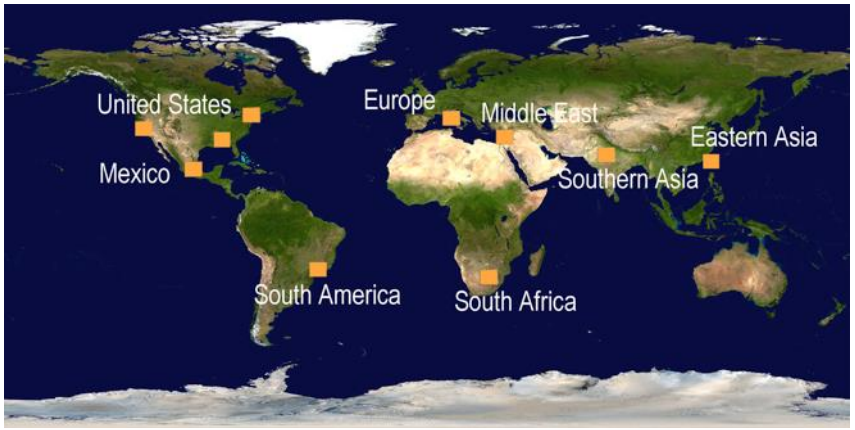


Investigation

Obtain data for globally distributed Primary Target Areas

- Instrument observations
- Ground station observations
- Chemical transport model outputs
- Health records

Obtain data for globally distributed Secondary Target Areas, Calibration/Validation Target Areas, and Targets of Opportunity



Analyses and Findings

Reporting on

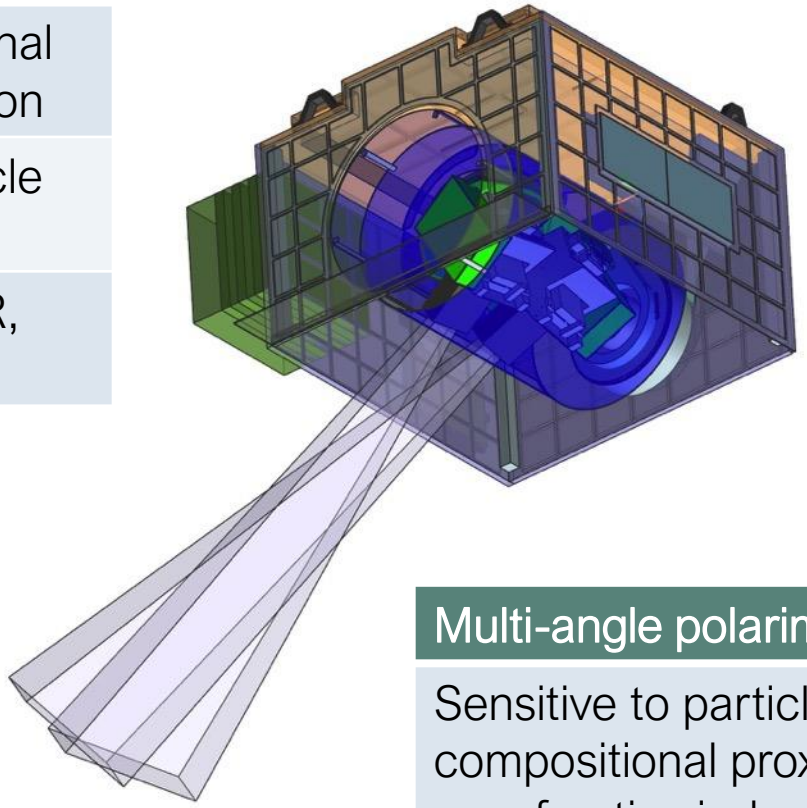
- Epidemiological investigations of health impacts of particulate pollution
- Other mission science
- Instrument performance, calibration, and validation

Imager can integrate multiple observing modalities

Observing modes

Multi-angle radiometry

- Enhances the aerosol signal relative to surface reflection
- Sensitive to aerosol particle size and shape
- Precursors: MISR, AATSR, POLDER, AirMSPI



Broad spectral coverage

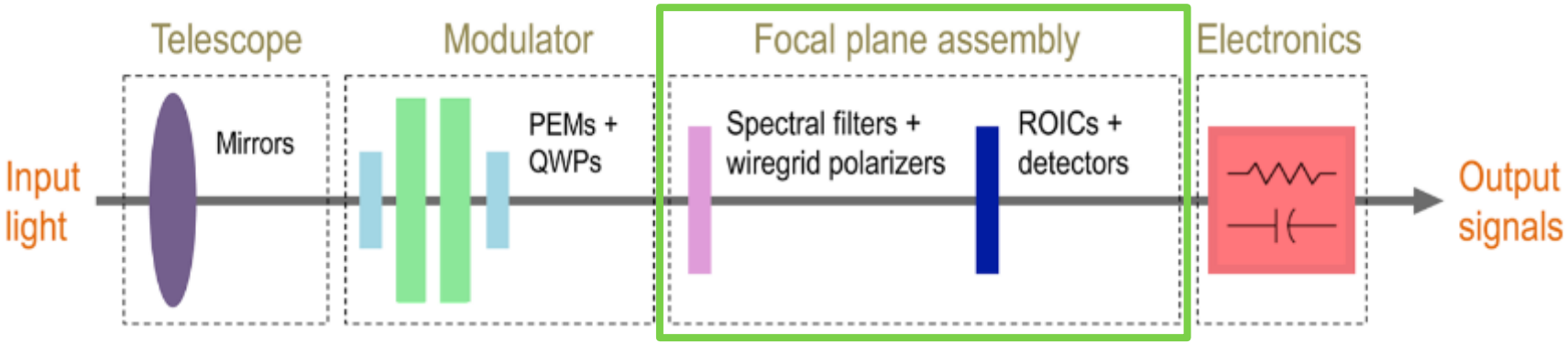
- UV: aerosol absorption and height
- VNIR: Fine mode aerosols
- SWIR: Coarse mode aerosols
- Precursors: MODIS, TOMS, OMI, GLI

Multi-angle polarimetry

- Sensitive to particle size and compositional proxies such as refractive index
- Precursors: POLDER, airborne RSP, AirMSPI

Camera Architecture

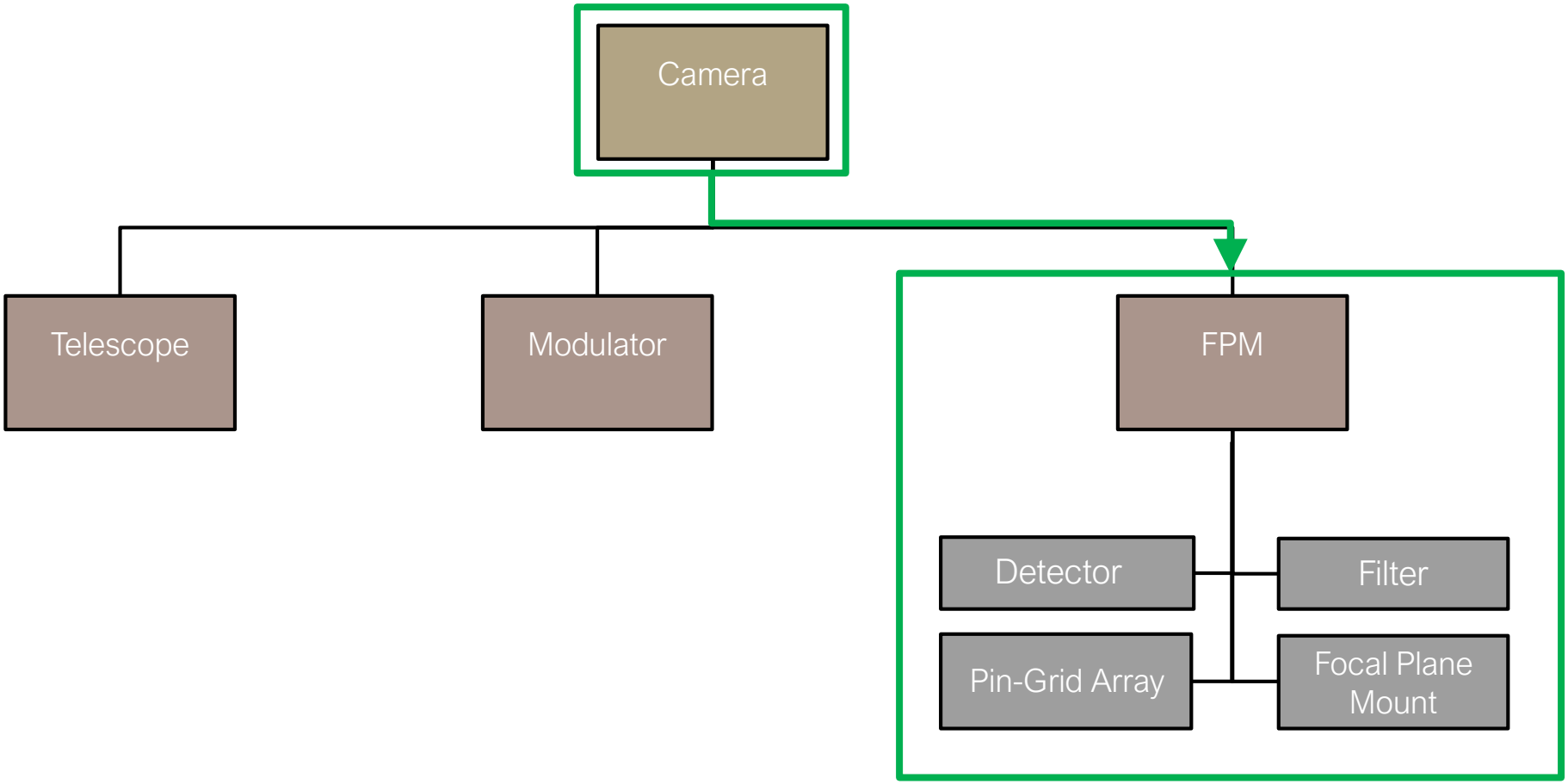
Instrument definition and block diagram



- ✓ The instrument is a gimbaled pushbroom camera system
- ✓ The camera architecture uses the spectropolarimetric imager approach developed for AirMSPI and AirMSPI-2
- ✓ Detector rows are overlaying with stripe spectral filters and patterned wiregrid polarizers
- ✓ Polarization signals are modulated using photoelastic modulators (PEMs) and achromatic quarter-wave plates (QWPs)
  - Modulation provides significantly greater accuracy than static polarimetry

Focal plane module subsystem

Focal Plane Module (FPM)



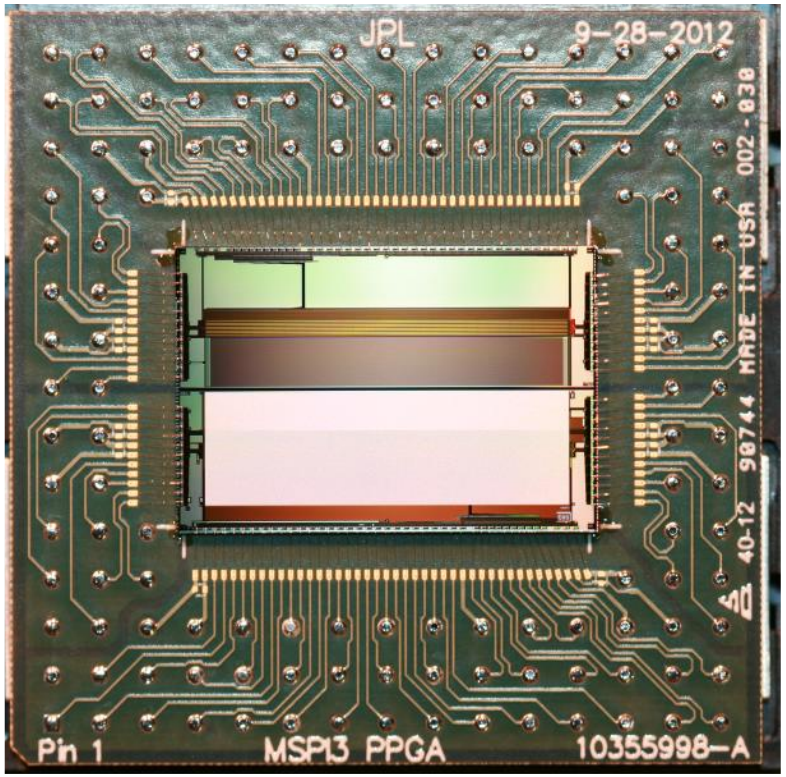
FPM Design Requirements

Focal Plane Module

- ✓ Several requirements are imposed on the FPM design, including:
  1. Electronic Interface – Power, housekeeping, and data rates
  2. Filter smoothness and cleanliness – minimize stray light
  3. Dark current levels – ensure adequate SNR for science req's
  4. Pixel arrangement – dictated by design at the ROIC level
  5. Spectral quantum efficiency – UV/Vis silicon photodiodes, IR HdCdTe detector

Focal Plane Detector

Focal Plane Module

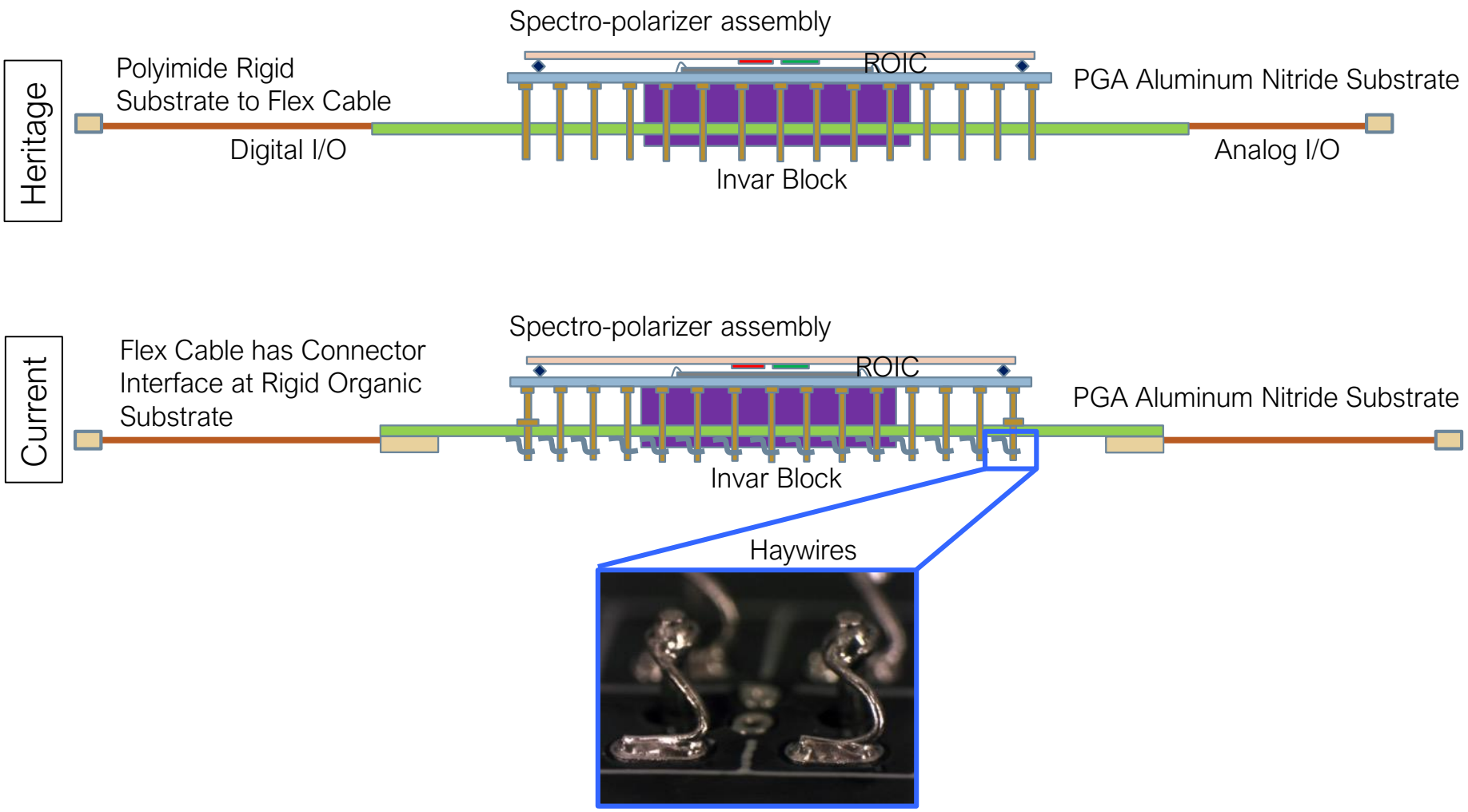


ROIC detector array mounted on a test board showing 130 wire bonds

- ✓ The UV/VNIR and SWIR ROICs share the same reticle and have the same number of pixels (1280 pixels × 128 rows) and pixel size (15 μm × 15 μm)
- ✓ SWIR row pitch is 15 μm and the UV/VNIR row pitch is 20 μm
- ✓ UV/VNIR array uses integrated (on-chip) photodiodes, and the SWIR array uses hybridized HgCdTe p+/n photodiodes (Teledyne)
- ✓ UV/VNIR and SWIR arrays are separated by a gap
- ✓ The two designs are electrically isolated, except for the common substrate

Packaging approaches for FPM imagers

Focal Plane Module



Proposed jumper-wired connections

Solid core technology demonstrated

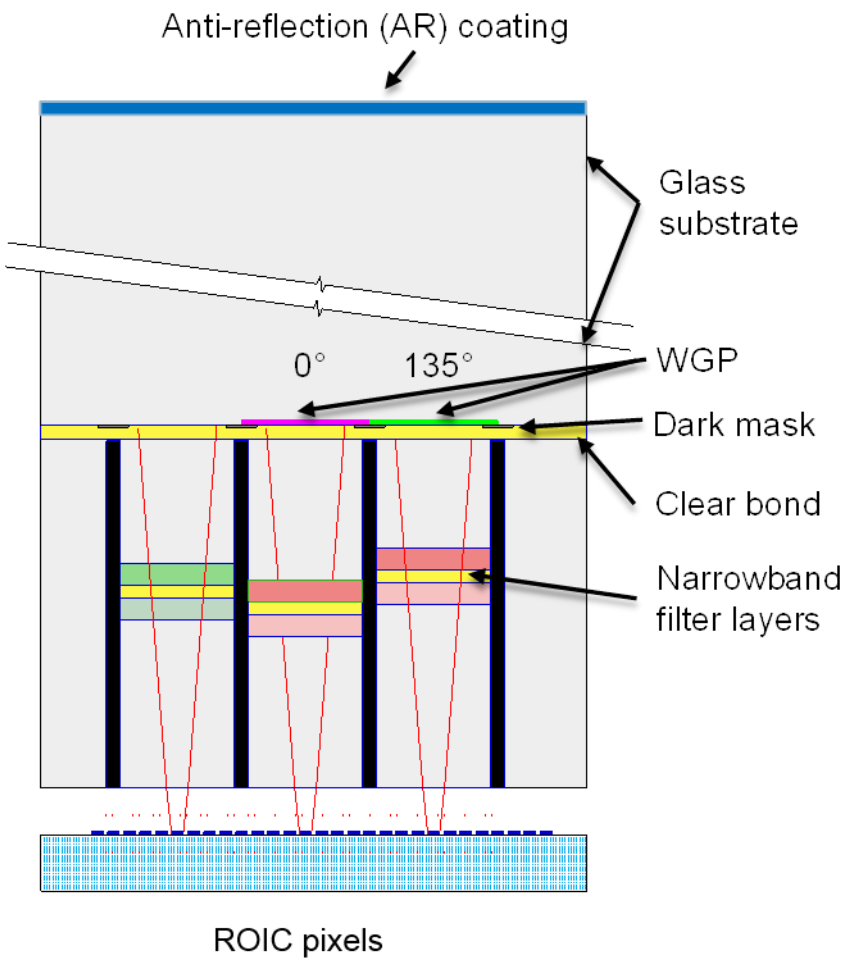
Focal Plane Module

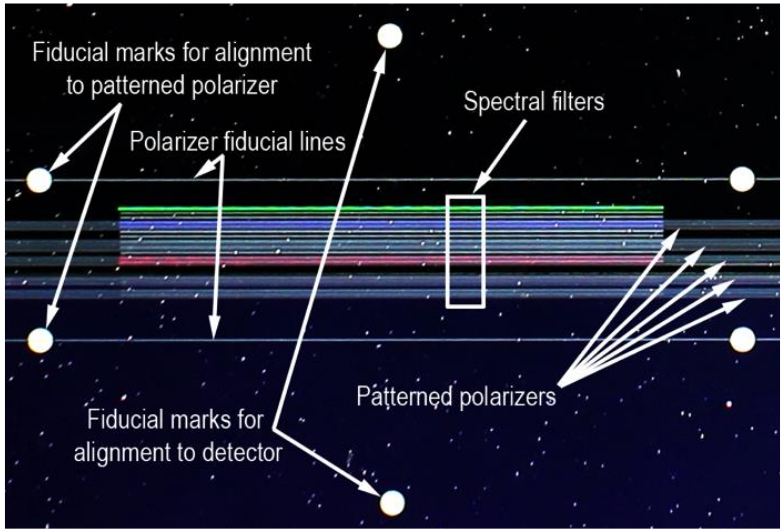
	Heritage (AirMSPI-2)	Current design	Implementation
Packaging	CPGA/rigid-flex	CPGA/board	Standard engineering practice
	Soldered CPGA	Jumpered wires	Tested for stress relief
Electronics Interface	Connectors on flex	Connectors on board	Streamlined mate/demate
ROIC design	Minor fixes post-fab	Peer-reviewed fixes incorporated	ROIC fabrication

- ROIC is a schedule-critical item
- ROIC is well understood, mods use proven practices
- All functionalities from design baseline are implemented in the current instrument
- Wafer screening process underway to identify candidates

Spectropolarimetric filter assembly

Focal Plane Module





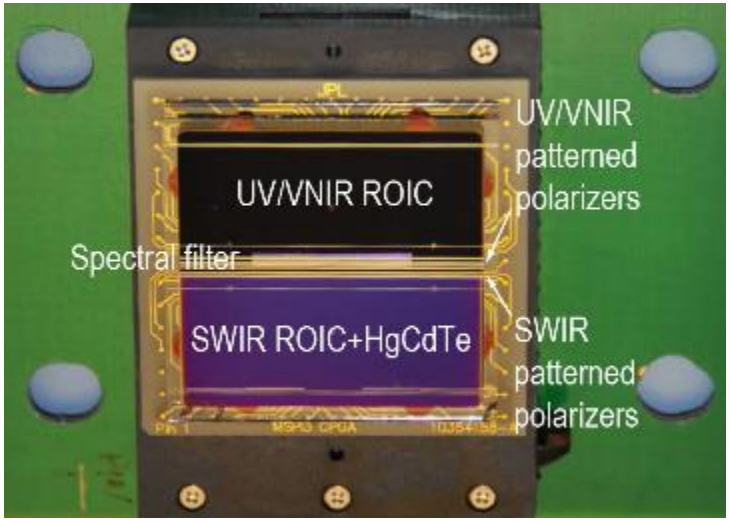
- ✓ Simultaneously front- and back-lit photograph of the AirMSPI-2 spectropolarimetric filter
  - Shows the stripe spectral filters and patterned polarizers
- ✓ Unique integrated assembly which starts from a wiregrid polarizer substrate
- ✓ Butcher-block type filter assembly is aligned and built directly onto polarizer substrate

Integrated Detector and Filter

13

Focal Plane Module

Band	Center wavelength (nm)	QE (%)*	Active detector rows
1	365	4	1
2	385	8	1
3	415	20	1
4	445	27	2 (polarimetric)
5	550	50	1
6	645	52	2 (polarimetric)
7	749	33	1
8	762	33	2
9	867	17	2
10	945	6	2
11	1035	72	4 (polarimetric)
12	1610	75	1
13	1880	80	1
14	2125	82	1



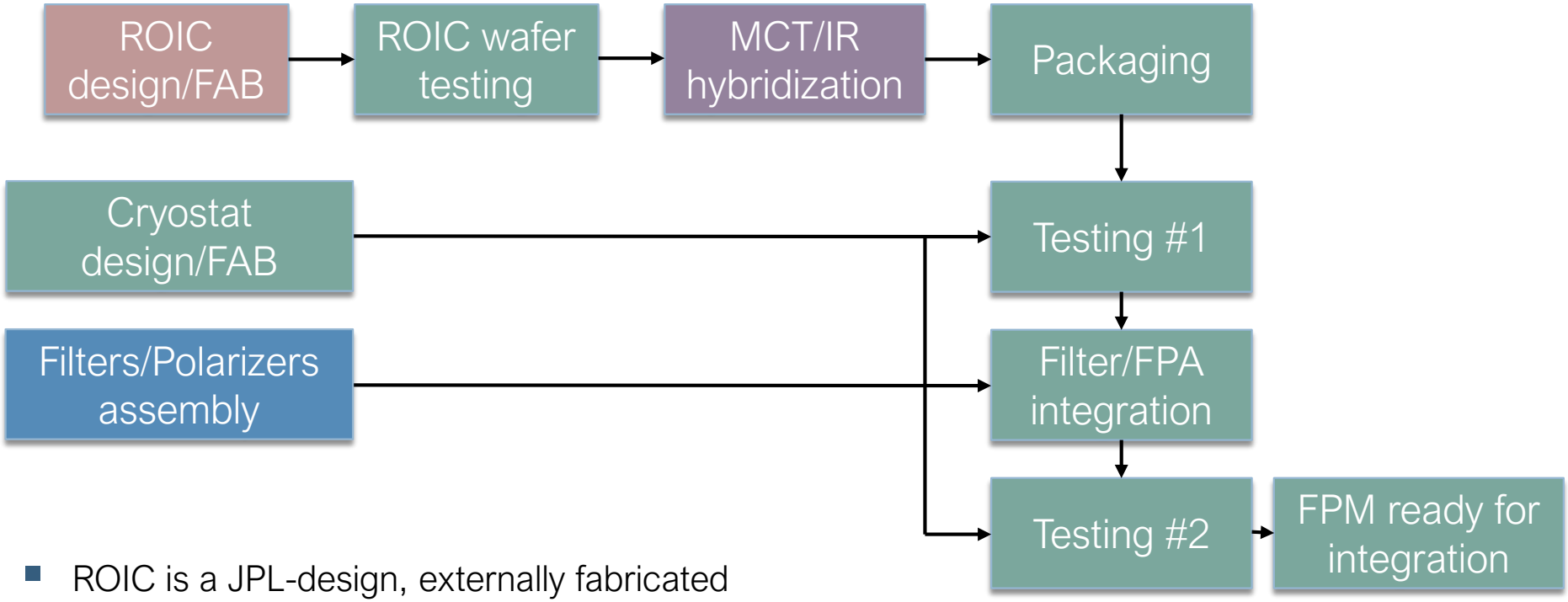
Filter aligned to the detector array and bonded to the custom ceramic pin grid array

UV/VNIR array | SWIR array

*Quantum efficiency based on previous detector performance

Assembly/testing flowchart

Focal Plane Module



- ROIC is a JPL-design, externally fabricated
- Wafer screening occur before hybridization of MCT detector
- Testing #1 will verify most of the electrical functionalities of the ROIC/detector
- Testing #2 will verify all the opto-electrical functionalities of the FPM

Conclusions

- ✓ Spectropolarimetric imagers based on pushbroom cameras are presented
- ✓ Integrated capabilities of multi-angle radiometry, broad spectral coverage, multi-angle polarimetry drive epidemiological investigations of health impacts of particulate pollution
- ✓ JPL-designed ROIC allow for UV/Vis and IR sensing on the same chip
- ✓ ROIC + spectropolarimetric filters will constitute the focal plane modules to be integrated at the camera level